Selection of equipment service option, estimation of equipment maintenance costs, and comparative costs analysis

Brooke Army Medical Center, Fort Sam Houston, Texas

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March 1999

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
AUG 1998	**Final**	**Jul 1998 - Jul 1999**

4. TITLE AND SUBTITLE
Selection of equipment service option, estimation of equipmentmaintenance costs, and comparative costs analysis Brooke Army Medical Center, Fort Sam Houston, Texas

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Lieutenant Samuel T. Olaiya, USN

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Brooke Army Medicsl Center Fort Sam Houston, TX 78234-6200

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Army Medical Department Center and School Bldg 2841 MCCS-HRA (US Army-Baylor Program in HCA) 3151 Scott Road, Suite 1412 Fort Sam Houston, TX 78234-6135

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
3-99

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT
Due to the increasing cost of health care, it behooves health care administrators to continue to look for ways of doing business cost-effectively without jeopardizing quality of care or limiting access to care. The purpose of this study was to: 1. Develop a decision making model that could be easily used by managers to evaluate and select appropriate service options. 2. Develop a maintenance cost estimation model. 3. Evaluate the efficiency of Brooke Army Medical Centers(BAMC) equipment management program. To address the first concern, the JUDGE model was used to breakdown decision into a list of attributes that influence what action would be ultimately taken. With regard to maintenance costs estimation, a retrospective study, based on a sample of 119 observations from Brooke Army Medical Centers (BAMC) property accounting system, was done to determine if there was a statistically significant difference in maintenance costs based on service option, equipment age, acquisition cost, equipmenttype and usage rate. As for the comparative costs analysis, performance ratios were utilized to evaluate the efficiency of BAMC in comparison to two other medical centers. Overall, this study showed that cost-effective equipment management techniques could be employed to monitor maintenance costs.

15. SUBJECT TERMS
Equipment Management

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**70**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Acknowledgement

First, I want to thank my present preceptor, Lieutenant Colonel David Heier whose professional guidance over the course of my residency at Brooke Army Medical Center has been superlative. He was asked to take over the responsibility of being my preceptor after my residency with FPA Medical Management was short-lived due to the lay-off of my former preceptor. He did so without reservation, and for that, I am grateful.

I also want to seize this opportunity to thank my reader, Lieutenant Commander Daniel Dominguez for guiding me through this project. His suggestions and comments markedly improved this study.

My gratitude also goes to Dr. Ken Finstuen, my Health Care Research Methods Professor. The knowledge that I gained from his class helped me immensely in developing the organization and approach to this study.

Finally, to my loving wife and children whose unflinching support and help have made the prompt completion of this project a reality, I say thank you.

Abstract

Due to the increasing cost of health care, it behooves health care administrators to continue to look for ways of doing business cost-effectively without jeopardizing quality of care or limiting access to care. The purpose of this study was to:

1. Develop a decision making model that could be easily used by managers to evaluate and select appropriate service options.
2. Develop a maintenance cost estimation model.
3. Evaluate the efficiency of Brooke Army Medical Center's (BAMC) equipment management program.

To address the first concern, the JUDGE model was used to breakdown decision into a list of attributes that influence what action would be ultimately taken. With regard to maintenance costs estimation, a retrospective study, based on a sample of 119 observations from Brooke Army Medical Center's (BAMC) property accounting system, was done to determine if there was a statistically significant difference in maintenance costs based on service option, equipment age, acquisition cost, equipment type and usage rate. The techniques of hierarchical multiple regression analysis were used to test the hypotheses that each independent variable specified in the model contributed uniquely to the variance in maintenance costs. The result showed that the full model is statistical significant, $\underline{R}^2$=.529 with

$F(8,110)=15.44$, $p<.05$. For the restricted multiple regression model, the R^2s were .231, .484, .444, .529, and .528 for service option, equipment age, acquisition cost, equipment type, and usage rate respectively. The first three predictor variables were found to be statistically significant with $F(1,110)=69.59$, $F(2,110)=5.25$, and $F(2,110)=9.93$, $p<.05$ respectively. Equipment type and usage rate were not found to be highly predictive, with $F(1,110)=0$, and $F(2,110)=0$, $p<.05$ respectively. As for the comparative costs analysis, the performance ratios showed that BAMC needed better oversight of its equipment management program. Overall, this study showed that cost-effective equipment management techniques could be employed to monitor maintenance costs.

Table of Contents

List of Tables

Introduction

Health care costs constitute a significant portion of the United States Gross Domestic Products (HCFA, 1997). Over the years, cries of excessive health care costs have been emanating from individuals who have to foot their medical bills, businesses who bear some of the costs of the employees' health care costs, politicians who have to make sure that programs such as Medicare and Medicaid are adequately funded, and even from some of the health care facilities who are struggling to remain solvent and competitive.

The military health system has not been immune from these exorbitant health costs. In view of the fact that the more money that is expended on military health system the less that is available to fund other defense initiatives relating to military readiness, projection of power, and updating and procuring military infrastructures; sensitivity to increasing health care costs has become even more pronounced in the military. This is especially true in the current government budgetary atmosphere that stresses fiscal responsibility and dishes out slim Department of Defense funding (Stockholm International Peace Research Institute, 1998). It, therefore, behooves, health care administrators, especially those of us in the military, to continue to look for ways of doing business cost effectively without jeopardizing quality of care or

limiting access to care.

One of the main culprits blamed for excessive health care costs is technology (Williams & Torrens, 1993). The rate of change in technology has been explosive, and this is reflected in technology costs, which have steadily increased over the past years (HCFA, 1997). Millions of dollars are expended every year in the purchase of medical equipment. In order to ensure that consistent quality health care is provided to the beneficiaries, and in order not to jeopardize their safety, it is imperative that the equipment used in their treatment be in top notch condition at all times. This means proper, prompt and adequate maintenance of all medical equipment. Consequently, medical equipment maintenance constitutes a major portion of a health care facility’s operating expenses (Tran, 1994). The pertinent question, therefore, is: Is there is a potential cost savings opportunity in medical equipment maintenance programs? That is the main question that this study explored.

Literature Review

Before delving into and further exploring possible answers to the above question, it is vital to identify the methods used, and conclusions reached, by studies that have been conducted in the area of medical equipment maintenance. First of all, since the continuous growth in technology is one of the reasons cited for increasing health care costs, what does the literature have

to say about managing technology?

Technology Assessment and Management

Managing technology assets effectively is essential if health facilities are going to meet the demand for greater operating efficiency (Halverson, 1995). Halverson also stated that it is critical that health care organizations bring technology acquisition in line with their overall strategic direction. In other words, top level management should focus their financial resources on acquiring the most advanced technology only when it is absolutely needed. The acquisition strategy should include leasing and acquiring lower-cost refurbished equipment. If health facilities can prioritize their needs and bring them in line with their institution's overall strategic plan, they will have taken a major step toward the financial stability necessary to remain competitive in the future (Halverson, 1995).

It is also essential that health facilities have in place medical equipment replacement criteria. This will help to avoid unnecessary costs associated with premature, inappropriate or simply unneeded equipment purchases (Fennigkoh, 1992). Fennigkoh proposed the use of a medical equipment replacement model to recommend and prioritize equipment replacement based on a "yes or no" scoring technique. The model contains ten attributes addressing four primary replacement issues: equipment

service and support, equipment function, cost benefits, and clinical efficacy. This model established a framework within which an issue can be further rationally evaluated.

Noting that selecting medical equipment can be perplexing and chaotic, Hostutler (1996) presented a three-phase process to evaluate and standardize medical equipment selection. The planning phase consisted of need assessment, market research, screening, and trial scheduling. The second phase entailed engineering evaluation, clinical evaluation, financial evaluation, and site visits. The final phase included discussion of evaluation results, selecting standard equipment and recommending a standard.

Economic evaluation techniques such as cost-benefit analysis, cost-effectiveness analysis, and cost-utility analysis can also be used to assist policymakers and health care executives in decision making with regard to the acquisition of technologies (Adang, Dirksen, & Engel, 1995). It has never been easy for a hospital to effectively analyze the benefits of technology acquisitions as there are often many vague qualitative issues and misleading assumptions that lead to unrealistic answers (Johnson & Morrison, 1995). Nevertheless, economic evaluation techniques can be used to investigate the costs and benefits associated with the decision to acquire a particular technology.

Cost-benefit analysis is an application of the theory of resource allocation to the acquisition of technology. Cost-benefit analysis measures both costs and benefits in monetary units. The costs of a program are ideally measured as opportunity costs, which can be defined as the benefits of the best alternative program, while benefits are defined as the maximum willingness to pay for the project (Adang, Dirksen, & Engel, 1995). One of the limitations of this approach to technology assessment is that in health care, it is difficult to assess all the benefits in monetary units.

The cost-effectiveness analysis approach tries to rectify the limitation of cost-benefit analysis by measuring the costs of technology in monetary units and the effects in physical units. Cost-effectiveness analysis is well suited to studies that focus on the comparison of a new technology with an existing alternative with homogenous outcome. However, when different 'effect' parameters are being investigated, cost-effectiveness analysis is not helpful in making a rational choice between medical technologies that cover different health-care areas (Adang, Dirksen, & Engel, 1995).

It is worth mentioning that cost-effectiveness analysis is a complex undertaking (Mullay, 1996). Designing standards to sufficiently and flexibly account for the rich set of statistical issues, which might present themselves across a wide

array of studies, is a formidable task. If the standards are set too rigidly, or if they fail to recognize the complexity of undertaking statistical cost effectiveness analyses, the information that emerges will likely be of limited value to its consumers.

The third evaluation approach advocated by Adang, et al. is the cost-utility analysis. This approach is an attempt to correct some of the limitations presented by the cost-effectiveness analysis. Cost-utility analysis attempts to measure the subjective satisfaction that people derive from consuming health care. The technologies, which are utilized in providing the health care, can be compared by constructing a cost per quality-adjusted life year (QALY). Therefore, with a cost-utility analysis, it is possible to compare the cost per QALY of different interventions; if the same method for determining cost and utility is used (Adang, et al, 1995).

Of course, technology management is more than the comparison of technologies. It should be a program that influences strategic planning and policy development by balancing the power, influence, and interests of key physicians to build a consensus for the future (Gordon & Tan, 1992). In the final analysis, newly acquired technologies should help resolve problems, provide fiscal advantages, reinforce clinical strengths, meet regulatory requirements, and enhance currently

owned technologies (Gordon & Tan, 1992). Moreover, ethical, legal, and social considerations must not be overlooked (Jaros & Boonzaier, 1992).

Equipment Maintenance Management

Another important factor that should be carefully considered prior to making the purchase decision relates to maintenance requirements (Bluemke, 1989). According to Bluemke, the one constant involving equipment failure is that it is unpredictable in both timing and seriousness. He, therefore, proposed a fundamental rule: after the purchase or lease of new technology equipment, the buyer, not the vendor, should control all aspects of the equipment. In Bluemke's view, this is important because development costs mislabeled as maintenance can result in extreme cost without recourse. However, maintenance on established technology can be treated with more flexibility because there is a significant amount of data available on maintenance.

Quality must not be overlooked in the medical equipment management process. Most of the activities carried out within a modern hospital are based on widespread use of equipment and technology, the efficiency of which can directly influence the quality of services offered to the patient in terms of: safety of use; diagnostic or therapeutic accuracy; and timely provision of medical services. Therefore, quality assurance must be first

and foremost when dealing with equipment maintenance. When quality is injected into the management of medical equipment, the result is usually a significant reduction in downtime and maintenance costs (Rainer, Menegazzo, & Weidmerl, 1996).

This leads to two questions that Rice (1996) tried to answer in his study. The two questions that he posed were:

1. What failures are actually preventable and what steps are necessary to prevent them?
2. When should specific steps be performed to effectively prevent the failures?

In answering these questions, Rice noted that it might well be that maximization of safety and effectiveness lies not with preventive maintenance, but with predictive maintenance. In other words, Rice’s suggestion was that effective preventive maintenance needs may not be periodic but may be a function of utilization and environmental factors. Therefore, utilizing traditional statistical methods, such as mean time between failures (which is a central tendency), may not be sufficient in identifying and predicting pattern extremes that are necessary for optimal preventive maintenance. Rice contended that although traditional moment statistics, such as the mean, will remain useful tools in the management of inspection and preventive maintenance effectiveness, the changing healthcare and technology environment demand more responsive tools for

assessment and prediction. He, therefore, suggested the exploration of measures such as the dimension of chaos, approximate entropy (a measure of the intrinsic irregularity of the unlikelihood of repetitions in pattern), and the Hurst exponent (a measure of the persistence or memory of past effects in current behavior) in an effort to better model preventive maintenance performance.

Maintenance Service Options

Wickesser (1994) provided an overview of contract options, contract considerations, and examples of negotiation strategies. Wickesser identified four equipment service options. The first is the manufacture/vendor service option. With this option, the manufacturer provides a full range of service including system upgrades and field modifications to their equipment. Another option discussed by Wickesser is "third party service". This option uses an independent service provider to fulfill repair and maintenance requirements. The third option is insurance coverage. This option allows the facility to call a preferred service firm whose invoice for time and materials will subsequently be reimbursed by the insurance company. In-house service is the last option discussed by Wickesser. This option can be cost effective and timely when manufacturer training, service manual, technical support and parts are readily available. When a facility decides to enter into a maintenance

agreement with a manufacturer or an independent third party firm, there are five different types of contracts that can be entered into: full service, repair-only, preventive maintenance only, parts-only, or some variations of full-service or repair only contract (Wickesser, 1994).

It is important to point out that long term service contracts may sometimes not be in the best interest of the healthcare facility. This is due to the fact that long-term service contracts are hard to cancel, do not allow for effective management control, and most important, do not allow for cost reductions (Bluemke, 1995). Even though long term service contracts are comprehensive with regard to service or part replacement, they constrain the equipment managers' flexibility in the allocation or redistribution of maintenance dollars. This lack of management control can be very devastating financially to a facility in today's rapidly changing healthcare environment (Bluemke, 1995). Bluemke suggested time-and-materials basis service contracts because the same benefits offered by the long-term contracts can be obtained at a significantly lower cost.

Finally, most of the studies done in the area of service contract management suggest that consolidation of equipment service contracts might be beneficial. Consolidation provides unique opportunities to reduce equipment costs (du Toit, 1995).

This is especially true for health systems with several facilities requiring equipment maintenance support. Consolidation allows a health system to bring individual equipment service contracts under one agreement. The result is a reduction in the overall cost and in the number of invoices and transactions (Gibson & Jergenson, 1995a). The practice of consolidation of service contracts is being utilized by large hospital systems like Columbia/HCA Healthcare Corporation as well as small systems, such as Sharp Healthcare, a San Diego-based group comprising six acute care hospitals (Anonymous, 1997).

In order to reap substantial benefits from consolidation, du Toit (1995) provided steps that should be followed by the facility. The steps included collecting data on service contracts and equipment not supported in-house, analyzing the data, evaluating the market, finding out all that is possible about the current service provider, and presenting information to all vested parties.

Theoretical Framework

Without a comprehensive study that examines the equipment maintenance program as a whole, managers will continue to make sub-optimal decisions with regard to the best service options. Moreover, if administrators do not closely monitor and take an active role in the management of the equipment maintenance

program, potential savings, which may be applied to the purchase of additional equipment or to finance other viable programs in a medical treatment facility may never be realized. The bottom line is that inefficiency in its equipment maintenance program will limit the amount of healthcare that a medical treatment facility can provide to its beneficiaries. This was the driving force behind this study which three-fold purpose was to:

1. Develop a decision making model that could be easily used to evaluate and select appropriate service options.
2. Develop a maintenance cost estimation model which managers could easily interpret for distinguishing between variables that significantly contribute to cost variance and those that do not.
3. Evaluate how well Brooke Army Medical Center's (BAMC) equipment management program compared to that of other facilities of similar size and workload.

In addressing the first objective, this study, using the JUDGE model, provided a decision making tool that reduced the decision to a list of attributes that would influence which action would ultimately be taken. The attributes which are relevant to making a decision as to which service option to select for a particular type of medical equipment, and which are necessary for the development of the model referred to in the first objective are listed in Appendix A.

With regard to the second objective, a maintenance cost estimation model was developed based on five independent variables: service options, equipment age, acquisition cost, equipment type and rate of usage (Appendix B). The model was used to examine the belief that maintenance costs is a function of these five independent variables. The main hypothesis was that maintenance costs did not vary as a function of these five independent variables. This model was tested for the effect of all variables and for each variable independently.

Finally, to satisfy the third objective, performance indicators such as biomedical repair cost per repair hour, biomedical repair expense per case-mix adjusted disposition, and biomedical repair expense per patient visit were investigated. Again, the objective was to determine how effective the facility was in monitoring its equipment maintenance costs, and to ensure that it was not paying for unnecessary repairs and maintenance.

Methods and Procedures

Service Option Evaluation

The literature pointed to the fact that there are many different service options offered by equipment maintenance organizations (Wickesser, 1994). They all promise great service at reasonable cost. However, this study posits that a careful and thorough analysis of what they have to offer might reveal significant differences in cost and quality between service

options. This study, therefore, assessed and evaluated six service options.

The service options evaluated were in-house service, manufacturer contract, manufacturer demand, third party contract, third party demand and maintenance insurance. The object of interest was providing an acceptable level of maintenance service at a reasonable and fair cost.

The JUDGE model was employed to investigate which service option to select, when equipment maintenance of radiology or laboratory equipment is needed.

The relevant attributes, which were utilized in the development of the JUDGE model, are listed in Appendix A. The Brooke's Army Medical Center's equipment manager assigned a rating to each attribute based on its desirability (Appendix C). The rating scale ranged from *1* to *9*. A rating of *9* denoted "extremely desirable", while a rating of *1* translated to extremely undesirable. These attributes were coded using numbers ranging from *4* to *-4.* Number *4* corresponded to *9*, *0* corresponded to *5*, and *-4* corresponded to *1* in the first scale.

Recoding allowed for clear delineation between desirable and undesirable attributes. Negative letters corresponded to undesirable attributes while positive letters represented desirable attributes. The negative signs were not used in the original scoring procedure in order to avoid coding errors.

The sum of the coded ratings for all of the attributes was divided into *100* resulting in a scaling factor. This scaling factor was then multiplied by the coded rating for each one of the attributes to arrive at the rescaled rating. Next, the attributes of the six alternatives were assigned expected utilities. These were the probabilities of the attainment of desirable or undesirable outcomes. The expected utility for some attributes, such as Cost (of the contract) and Response Time were calculated objectively. On the other hand, the expected utility of attributes such as Manufacturer's Support and Organization Stability were based on "best guess".

Finally, the rescaled ratings were multiplied by the expected utility of the attributes for each alternative to obtain the composite weight. The alternative with the higher totaled weighted composite represented the best option. Moreover, the evaluation of the service contracts was based on the top and bottom three attributes of each of the service options. This approach to evaluating service contracts went beyond the "yes or no" scoring technique advocated by Fennigkoh (1992).

Costs Estimation

With respect to determining the effect of all identified independent variables and for each variable independently on maintenance costs, the population considered was all of the

radiology and laboratory equipment maintained by BAMC. This study concentrated on radiology and laboratory equipment because the lion's share of a maintenance budget in almost every hospital is spent in these areas (Koenig, 1992). Since, it will be time prohibitive to investigate the population, a sample size of 119, that was representative of the population, was randomly selected. This sample size is required to attain results with accuracy level no less than +/-10 at a 95 per cent confidence level.

The data used in this study were obtained retrospectively from the Army Medical Department Property Accounting System. This system was used as the data source because of its reliability. It is an official Army database, and the data therein are verified through internal audits and periodically checked during scheduled inspections. The period of investigation was October 1, 1997 through September 30, 1998. The data, therefore, represented maintenance costs for one fiscal year.

The main research interest, in this part of the study, was to find out what effect service contract option, equipment age, acquisition cost, equipment type and rate of usage had on maintenance costs. Appendix C showed the independent variables, which were entered into a multiple regression model. The effect of each one of these independent variables was controlled for by

the use of mutually exclusive categorically exhaustive binary variables.

Moreover, the techniques of hierarchical multiple regression analysis were used to test the hypothesis that each independent variable specified in the model contributed uniquely to the variance in maintenance costs. This of course went beyond the one-way analysis of variance or the t-test for means difference in that the comparisons of the means of the predictor variables to each other and to the grand means were done simultaneously.

Furthermore, in order to determine the unique effects of each predictor variable while controlling for other predictor variables, the coefficient of multiple determination for the full model was calculated. Subsequently, the coefficients of multiple determination were calculated for each predictor variable while holding other variables constant. These coefficients of determination were also used to determine the validity and predictive value of the study. Finally, F statistics were calculated for the full model and the restricted models. The calculated F statistic and critical value, at a significance level of .05, served as the basis for testing the hypothesis that maintenance costs varied based on type of service contract, equipment age, acquisition cost, equipment type and rate of usage. This study also tested the sub-

hypotheses that each one of the five independent variables individually contributed to maintenance costs.

Comparative Costs Analysis

In order to evaluate the efficiency and effectiveness of BAMC's equipment management program, a comparative costs analysis was conducted. BAMC's biomedical repair expenses and maintenance costs for fiscal years 1996, 1997 and 1998 (Appendix D) were compared to those of 2 other medical treatment facilities of about the same size and workload.

The type of medical treatment facility focused on in this study was an army medical center with a major graduate medical education program. Two medical centers, besides BAMC, which fitted this description, were Madigan Army Medical Center (MAMC) and Triple Army Medical Center (TAMC).

BAMC is a 450-bed military medical center and a major teaching hospital based in Fort Sam Houston, Texas. It has over 3,200 healthcare professional providing a comprehensive array of services in major medical specialties to a beneficiary population of about 70,000. As for MAMC, it is a 414-bed teaching hospital serving over 175,000 beneficiaries. Madigan, which is considered the busiest medical center in the State of Washington, functions with a staff of over 3,000. The third medical center examined in this part of the study was TAMC. TAMC, a 432-bed U.S. Army medical center serves more than

750,000 eligible beneficiaries in the Pacific. It is the largest military medical facility in the region with a staff of over 2,500.

The first action taken was to allocate each facility's biomedical repair expenses among the three major service centers: outpatient services, inpatient services and dental services (for the purpose of this study focus was placed on the first two services). Allocating biomedical repair costs to these service centers allowed for the effective evaluation of the impact of the Biomedical department on the cost structures of the medical facilities.

The most logical allocation base for Biomedical repair services is actual usage. Therefore, the cost allocation was based on the repair hours provided (Appendix E) to the service centers by Biomedical department during the periods under investigation.

Efforts were also concentrated on collecting data for specific performance ratios: Biomedical repair expense to facility's total obligation; Biomedical personnel cost to total Biomedical repair expense; Biomedical repair expense per repair hour; Biomedical repair expense per case-mix adjusted disposition; and Biomedical repair expense per outpatient visit. The definitions of these ratios are provided in Appendix F. In

addition, the workload data used in the calculation of some of these ratios are provided in Appendix G.

It should be noted that in order to ensure that all of these ratios were comparable they were adjusted for changes in price levels. The index selected to convert 1996 and 1997 historical cost information into 1998 dollars was the Medical Consumer Price Index. The indexes for the periods 1996, 1997 and 1998 were 228.2, 234.6, and 242.1 respectively. The source of these indexes was the Bureau of Labor and Statistics, Consumer Price Index, Medical Care, All Urban Consumers.

For reliability purposes, the retrospective data for this analysis was obtained from the Medical Expense and Reporting System (MEPRS). This cost accounting system is an official DOD system, which is used by higher echelons such as DOD, Health Affairs to make funding allocation decisions.

The comparative costs analysis provided an objective framework for the comparison of BAMC's biomedical repair/maintenance expenses with those of two similar medical centers. First was the comparison of BAMC's calculated performance ratios to itself over time. The changes from year to year revealed whether BAMC's Biomedical department was improving its own level of efficiency and effectiveness over time. Secondly, the department's results were compared to those

of MAMC and TAMC in order to establish relative efficiency and effectiveness.

It is vital to note that the data, which were used in this study, were unclassified and not sensitive. In addition, there were no human subjects involved in the study, and there were no privacy act issues.

Results

Assessment of Service Options

Table 1 depicts the top three and bottom three weighted utility of each attribute for each alternative. For the In-house service option, the top three attributes were cost, response time, and quality of service. Conversely, the bottom three attributes were loaner equipment, penalty, and insurance. One of the bottom three attributes, penalty, was considered very undesirable. Penalty was undesirable because in some cases the manufacturer's warranties could be nullified if the facility opted to use service providers other than the manufacturer for equipment maintenance. On the other hand, cost, response time, and quality of service were desirable attributes. On-site biomedical technicians can promptly respond to requests for service. Quality of service is also enhanced because the in-house technicians, in addition to their technical skills, tend to work effectively with equipment vendors, hospital staff members, and hospital administrators (Tudor & Gemmill, 1994).

Table 1

Evaluation of Service Options

Service Option	Top 3 Attributes	Bottom 3 Attributes
In-house	2.86 Cost 2.14 Response Time 1.86 Quality	0.00 Loaner Equipment 0.00 Penalty 0.43 Insurance
Manufacturer Contract	3.14 Quality 2.14 Service Personnel 2.14 Qualifications	-3.57 Penalty 0.71 Insurance 0.71 No. of staff
Manufacturer Demand	3.14 Quality 2.14 Cost 2.14 Service Personnel	-3.57 Penalty 0.71 Insurance 0.71 No. of Staff
Third Party Contract	2.43 Quality 1.86 Cost 1.71 Service Personnel	-2.57 Penalty 0.46 Org. Stability 0.43 Manufacturer Support
Third Party Demand	2.43 Cost 1.71 Service Personnel 1.71 Response Time	-2.57 Penalty 0.43 Org. Stability 0.43 Manufacturer Support
Maintenance Insurance	3.57 Cost 2.00 Quality 1.71 Response Time	-2.00 Penalty 0.50 Training 0.46 Manufacturer Support

Finally, with in-house service option, the true facility's maintenance costs can be determined. This provides the healthcare organization with the opportunity to accurately budget and plan for the future (Bluemke, 1995).

Appendix B represented an assessment of the six maintenance service options. The sum of the weighted composites in this table indicated that the in-house service option was the best option, followed by manufacturer demand and manufacturer annual contract. In-house, manufacturer demand, and manufacturer annual contract occupied 18.43%, 18.36%, and 17.64% of the decision space respectively. The remaining service options: insurance, third-party annual and third-party demand contract occupied 16.46%, 15%, and 14.11% of the decision space respectively.

Costs Estimation

The mean and standard deviations for maintenance costs for the predictor variables are provided in Table 2. The mean maintenance cost (cost to maintain an equipment item for a year) for in-house service options was $496 and for annual contract option, $65,777. For equipment age, the mean maintenance cost ranged from $1,001 for new equipment to $5,821 for fairly new equipment. The mean maintenance cost for fairly used equipment was $3,847. With acquisition cost, the lowest mean was $57 for low-cost equipment and the highest mean maintenance cost was

$41,050 for high-cost equipment. For medium-cost equipment, the mean maintenance cost was $722. As far as equipment type is

Table 2

Descriptive Statistics

Predictors		Sample Size	Percentage	COST Mean	COST Standard Deviation
Service Option					
In-house		112	94	$ 496	$ 1,874
Annual Contract		7	6	65,777	91,579
	Total	119	100		
Equipment Age					
New		8	7	$1,001	$ 1,264
Fairly New		41	34	5,821	22,713
Fairly Used		70	59	3,847	28,979
	Total	119	100		
Acquisition Cost					
High		12	10	$41,050	$74,322
Medium		26	22	722	1,070
Low		81	68	57	62
	Total	119	100		
Equipment Type					
Laboratory		63	53	$ 102	$ 387
Radiology		56	47	9,100	37,265
	Total	119	100		
Usage Rate					
High Usage		83	70	$6,136	$30,820
Medium Usage		10	8	348	934
Low Usage		26	22	124	156
	Total	119	100		

concerned, laboratory equipment mean maintenance cost was $102, while radiology had the mean maintenance cost of $9,100. Finally, usage rate mean maintenance cost ranged from $124 to $6,136.

The result of the full multiple regression equation, $\underline{R}^2=.529$ is depicted in Table 3. This was a statistically significant finding, with $\underline{F}(8,110)=15.44$, $p<.05$. For the restricted multiple regression model, the $\underline{R}^2$s were .231 for service option, .484 for equipment age, .444 for acquisition cost, .529 for equipment type, and .528 for usage rate. Service option, equipment age, and acquisition cost were found to be statistically significant predictor variables with $\underline{F}(1,110)=69.59$, $\underline{F}(2,110)=5.25$, and $\underline{F}(2,110)=9.93$, $p<.05$ respectively. Equipment type and usage rate were not found to be highly predictive, with $\underline{F}(1,110)=0$, and $\underline{F}(2,110)=0$, $p<.05$ respectively. The implication was that equipment maintenance costs varied significantly based on service option, equipment age and acquisition cost. Therefore, these variables should be given careful consideration when making equipment maintenance decisions.

Table 3

Unique Effects Tested While Controlling for All Other Predictor Variables

Effects Tested	Coefficient of Determination/Level of Predictive Efficiency				
	R^2 Full	R^2 Restricted	Df_1	Df_2	F^a
COST					
Full Model	.529	0	8	110	15.44[a]
Service Option	.529	.231	1	110	69.59[a]
Equipment Age	.529	.484	2	110	5.25[a]
Acquisition Cost	.529	.444	2	110	9.93[a]
Equipment Type	.529	.529	1	110	0
Usage Rate	.529	.528	2	110	0

Note. n=119

F^a is significant $P < .05$.

Table 4 lists the unique variance accounted for by the individual predictor variables. This study showed that 29.8%, 4.5%, and 8.5% of the variance in maintenance costs were uniquely accounted for by service option, equipment age, and acquisition cost respectively. Service option accounted for the lion’s share of the variance. Based on this study, equipment type and usage rate contributed nothing unique to variance in maintenance costs. This may be due to the quality of new technologies. Modern microprocessor-based equipment is

increasingly reliable. The result is a greatly reduced number of breakdowns (Van der Putten et al., 1994) when usage rate is within the recommended manufacturer's guidelines.

Table 4

Unique Variance Accounted for By Predictor Variables

Predictor	Unique Variance Accounted For in Cost (%)
Service Option	29.8
Equipment Age	4.5
Acquisition Cost	8.5
Equipment Type	0
Usage Rate	0

Comparative Costs Analysis

The results of the study of BAMC's biomedical repair expenses for fiscal years 1996, 1997 and 1998 are depicted in Tables 5 and 6. Table 5 shows the costs allocated to outpatient and inpatient services based on repair hours. The direct expenses were costs directly attributable to the biomedical repair department. Total repair expenses were the addition of direct expenses and the overhead costs apportioned to biomedical department.

Table 5

Chargeable Medical Equipment Repair Expenses

Description	Expenses ($'000) BAMC	MADIGAN	TRIPLER
1996			
Direct Repair Expenses - Inpatient	1,658	983	1,369
Direct Repair Expenses - Outpatient	1,244	1,842	1,629
Total Repair Expenses - Inpatient	1,895	1,076	1,554
Total Repair Expenses - Outpatient	1,422	2,016	1,849
1997			
Direct Repair Expenses - Inpatient	1,353	1,228	1,205
Direct Repair Expenses - Outpatient	1,548	2,388	1,709
Total Repair Expenses - Inpatient	1,520	1,337	1,353
Total Repair Expenses - Outpatient	1,738	2,600	1,920
1998			
Direct Repair Expenses - Inpatient	1,292	667	1,263
Direct Repair Expenses - Outpatient	2,927	1,279	1,946
Total Repair Expenses - Inpatient	1,453	757	1,399
Total Repair Expenses - Outpatient	3,293	1,451	2,156

The performance ratios are shown in Table 6 and graphically illustrated in Figures 1 through 5 in Appendix H.

Biomedical repair expenses to the total facility's obligations: The ratio of BAMC's biomedical repair expenses to

the total facility's obligations was constant (1.5%) in 1996 and 1997. However, in 1998, this ratio jumped dramatically to 2.2%, an increase of 46.7%. For MAMC, this ratio was higher than BAMC's for 1996 and 1997, 1.6% and 2.2% respectively. TAMC's ratios for 1996 and 1997 (1.7% for each period) were also higher than those of BAMC's. In 1998, however, MAMC and TAMC experienced much lower ratios, 1.2% and 1.5% respectively, when compared with BAMC's 2.2%.

A justifiable question at this juncture would be: why the marked increase in BAMC's 1998 biomedical repair expenses? Further investigation of the dramatic increase in BAMC's 1998 biomedical repair expenses revealed that contracted services and supplies accounted for the major portion of the increase (Table 7). Contracted services increased by 99.4% from 1997 to 1998. In 1998, this expense item was $2,980,010 as opposed to $1,494,592 in 1997. Likewise, supply expenses went from $526,300 in 1997 to $967,694 in 1998, an increase of 83.9%. These increases were so significant that the savings generated from decreasing military personnel and travel expenses, in 1998, could not offset them. Specifically, in 1998, there was a 23.9% drop in military compensation, a cost savings of about $200,000. In addition, a 30.7% decrease in travel expenses yielded approximately $28,000 cost savings.

Biomedical personnel costs to total biomedical repair expenses: This ratio, which attempted to analyze personnel costs relative to total biomedical expenses, was 21.2% for BAMC in

Table 6

Performance Indicators

Period	BAMC (%)	MADIGAN (%)	TRIPLER (%)
	Total Biomedical Repair Expenses to Facility's Obligations		
1996	1.5	1.6	1.7
1997	1.5	2.2	1.7
1998	2.2	1.2	1.5
	Biomedical Personnel Costs to Total Biomedical Repair Expenses		
	BAMC (%)	MADIGAN (%)	TRIPLER (%)
1996	37.0	33.7	33.1
1997	36.3	28.6	33.0
1998	21.2	49.1	29.5
	Biomedical Repair Expense per Repair Hour		
	BAMC	MADIGAN	TRIPLER
1996	$124	$231	$121
1997	$125	$243	$122
1998	$246	$124	$183

Table 6 (cont'd)

Performance Indicators

Period	Biomedical Repair Expense per Case-Mix Adjusted Disposition BAMC	MADIGAN	TRIPLER
1996	$79	$52	$78
1997	$94	$89	$94
1998	$96	$66	$110
	Biomedical Repair Expense per Outpatient Visit BAMC	MADIGAN	TRIPLER
1996	$2.54	$2.04	$2.19
1997	2.81	2.75	2.45
1998	5.19	1.59	2.85

Note. The historical data were adjusted for inflation and based on 1998 dollars.

1998. This was considerably lower when compared to 1996 (37%) and 1997 (36.3%). This implied that BAMC expended more of its biomedical resources on equipment parts, supplies, purchased contracts, and other miscellaneous operational costs in 1998. When compared to MAMC and TAMC, BAMC's was the lowest in 1998. MAMC was 49.1% while TAMC was 29.5%.

Biomedical repair expense per repair hour: This appeared not to be a favorable trend for BAMC. Despite increasing repair

expenditures (Appendix G), the repair hours were decreasing. The repair hours for 1996, 1997 and 1998 were 34,000, 31,000 and 22,000 respectively. In 1996 and 1997, biomedical expense per repair hour were relatively constant, $124 and $125 respectively. There was, however, a dramatic increase in cost per repair hour in 1998. This cost was $246 in 1998, an increase of 96.8% when compared to 1997. In contrast, MAMC seemed to be experiencing decreasing costs per repair hour. It went from a high of $243 in 1997 to $124 in 1998, a 49% decrease. TAMC was also experiencing an unfavorable trend. Its biomedical expense per repair hour was increasing. In 1997 it was $122 as opposed to $183 in 1998, a 50% increase.

Biomedical repair expense per case-mix adjusted disposition: The increasing trend in biomedical repair cost per hour at BAMC was directly reflected in this ratio. At BAMC, there was an increase of 22% in this ratio between 1996 and 1998. For the same period, MAMC and TAMC ratios went up by 27% and 41% respectively. In monetary term, MAMC’s biomedical expense per case-mix adjusted disposition ($66), in 1998, was much lower than BAMC’s ($96) and TAMC’s ($110). Moreover, both BAMC and TAMC were experiencing increasing trend as opposed to

Table 7

BAMC 1996 to 1998 Itemized Biomedical Repair Expenses

Expense Type	1996 ($'000)	% Change	1997 ($'000)	% Change	1998 ($'000)
Civilian Compensation	893.0	-22.1	695.3	-3.6	670.6
Military Compensation	784.7	6.2	833.1	-23.9	634.0
Travel	47.4	94.2	92.1	-30.7	63.9
Communication	2.0	1.8	2.0	-3.4	1.9
Utilities	6.0	-25.3	4.5	-100.0	0
Printing	3.8	-78.7	.8	94.8	1.6
Contracted Services	1,940.9	-23.0	1,494.6	99.4	2,980.0
Custodial Services	.4	13,478.0	55.1	0.9	55.7
Education & Training	.1	1,697.4	2.6	370.2	12.4
Equipment	2.5	826.5	22.8	-67.6	7.4
Supplies	230.8	128.0	526.3	83.9	967.7
Advanced TDY Allowance	65.8	-51.6	31.9	-100.0	0
Miscellaneous	.4	-46.0	.2	-92.8	0
Total	3,977.8	-5.4	3,761.4	43.4	5,395.1

MAMC's decreasing trend in this ratio.

Biomedical repair expense per outpatient visit: For BAMC, this ratio seemed to be skyrocketing. The change in this ratio from $2.81 in 1997 to $5.19 in 1998 was very dramatic. It represented an 85% increase in repair costs per outpatient visit. This ratio did not compare favorably with those of MAMC ($1.59) and TAMC ($2.85) in 1998. The trend for BAMC was also increasing as it was for TAMC. MAMC was on a downward trend.

Discussion

The results of this study support the proposition that decision-making tools such as the JUDGE model can be used to effectively evaluate and select appropriate service options. The application of this model, in this study, suggests that the in-house and manufacturer demand service options represent the top two options. These two service options represent 18.43% and 18.36% of the decision space respectively. This finding is very much in line with the conclusion of most of the studies done in this area. Bluemke (1989) suggests that in-house service option is desirable and can be the least expensive. Moreover, Wagner (1992) asserts that paying for service on an as-needed basis, rather than paying a lump sum for service contracts, can results in savings of 15 to 20 percent annually. Furthermore, Bluemke (1995) contends that a well-managed time-and-material system for payment of equipment maintenance may be the most cost-effective

and efficient maintenance management method for some organizations. This does not mean that other types of service options are not viable. The fact that other service options such as manufacturer annual, insurance, third-party annual, and third-party demand contract occupy 17.64%, 16.46%, 15%, and 14.11% of the decision space respectively suggests that these service options cannot be completely overlooked when selecting appropriate service option. There are instances when one or two of these options might be better than in-house service option. For example, the in-house biomedical repair department may lack the technical expertise when it comes to servicing a particular type of equipment. Sometimes, it may not be economical to provide in-house service for certain pieces of equipment, and other times, liability issues may preclude the use of in-house repair department for the service of equipment, such as anesthesia machines, heart-lung machines, laser units and other specialized machines used in critical applications (Tran, 1994). The key is to identify the right attributes to help make decisions based on objective criteria (McGachey, 1996).

The JUDGE model will help equipment managers to support their choice of service provider in a more objective, quantifiable, and verifiable manner. In other words, with this model, informed decisions based on the use of data, rather than emotions, can easily be quantified, validated, and communicated

to stakeholders.

The hypothesis that a maintenance cost estimation model, which can identify variables that significantly contribute to variance in maintenance costs, can be developed is also supported by the findings. The regression model accounts for more than half (52.9%) of the variance in maintenance costs. Specifically, service option explains the largest amount of variance, 29.8%. In addition, equipment age and acquisition cost explains 4.5% and 8.5% of the variance in maintenance costs respectively.

Although the results do not support the hypotheses that equipment type and usage rate contribute uniquely to the variance in costs, equipment managers should not completely ignore these variables when making equipment maintenance decisions. The non-significant finding, for example, in usage rate could be the result of the fact that the ranges of usage specified in the model are all within the suggested manufacturers' maximum capacity. As long as usage rate is not beyond the recommended maximum capacity, normal wear and tear should be expected. Investigating equipment usage beyond recommended capacity may produce significantly different results. The finding may also be due to BAMC's excellent preventive maintenance program. All of the equipment items identified in the collected data were put on preventive

maintenance schedules. The Biomedical department appears to be very proactive in ensuring that all equipment is properly serviced according to schedules.

As mentioned earlier, the full regression model accounts for only 52.9% of the variance in costs. This suggests that additional variables such as frequency of preventive maintenance, and users' proficiency and level of training may be needed to increase the predictive value of this model.

The utility of the cost estimation model is that it can increase the managers ability to predict maintenance costs. Moreover, it can help focus the manager's attention on those variables that contribute most to the variance in maintenance costs. Finally, when consolidation of service contracts is being considered, the techniques applied in this study can be used to identify the variables that may significantly affect maintenance costs.

With respect to the performance ratios, they will allow for a better, objective assessment and monitoring of BAMC Biomedical department's efficiency and effectiveness. Tracking of these ratios can make useful comparisons over time.

The comparison of 1998 results with those of prior years provided an added perspective in the evaluation of the relationship of the current performance with past performance. Moreover, comparison of BAMC Biomedical department's ratios with

those of other similar medical centers provided additional insight into how well BAMC is performing compared with its peers. For example, the biomedical expense per repair hour, biomedical expense per case-mix adjusted dispositions, and biomedical expense per outpatient visit ratios clearly show that BAMC's expenses are increasing and that BAMC, in most cases, does not compare favorably with its peers. What was also significant about the findings was that there was no appreciable increase in BAMC's workload during 1998. In fact, BAMC's workload appeared to be on a decreasing trend. In this instance, BAMC can take either of two steps. It can either find ways to appropriately curtail its biomedical repair expenses so that they correctly reflect the amount of workload, or it can concentrate on increasing the number of beneficiaries that access the hospital and thereby increase the amount of services provided. However, increasing beneficiaries will not directly address the problem because the increased costs are not the result of fixed overhead expenses. Moreover, since the facility has better control on the amount of resources it decides to spend on biomedical repair, it will appear logical that efforts should be focused on controlling costs generated in biomedical department.

Costs can be controlled by encouraging competition among contractors when contracting with equipment service providers.

Rather than focusing on complete equipment maintenance contracts, ample consideration should also be given to other types of contracts such as parts only or labor only contracts. This will allow BAMC to maintain flexibility when choosing from a number of qualified maintenance contractors. The result will be increased ability to control and contain costs. However, care must be taken not to employ too many different vendors because such action may lead to incomplete and scattered equipment maintenance record. Also, it is imperative that the biomedical department does a meaningful analysis of maintenance costs prior to making equipment purchase decisions.

Although service contracts are attractive because of their use and perceived comprehensiveness, the cost may be too high (Bluemke, 1995). Therefore, BAMC's biomedical repair department, in conjunction with the resource management department, needs to monitor more closely the equipment service records to ensure that the facility is not paying for unnecessary repairs and maintenance. Moreover, inventory control mechanisms and adequate internal controls should be implemented to ensure that supplies and repair parts are accounted for properly. Otherwise, recent surge in supply and repair part expenses will most likely continue.

Other areas worth looking into for possible cost reduction are extended warranties and leases. It is widespread knowledge

today that technology changes rapidly (Van der Putten, Cooney, & Moran, 1994). Obsolescency can result in increased costs of operation. Leasing is an effective way of guiding against the risk of obsolescence. In addition, it is wise to bring suppliers and contractors into the loop when brainstorming some of the cost savings initiatives that might be of interest to BAMC. Many of these vendors deal with other medical facilities and have learned lessons that they may be willing to share, if approached.

Another important finding was that BAMC’s reduction of in-house repair personnel did not translate to overall savings in the biomedical repair budget. When contract services are substituted for in-house repair, careful consideration must be given to the effect on quality of service and the overall costs of operation. There must be effective oversight of service contracts; otherwise, potential savings will not be realized.

In this study, it was discovered that the savings generated from a cutback in military personnel was completely wiped out by the increase in contracted services. According to Bluemke (1989), in-house servicing can provide the lowest cost method, if it is not permitted to become simply a bugetable expense. Beyond the need to maintain an adequate level of well educated and trained staff, the finding further underscores the importance of the employment of a sound decision making model,

such as the JUDGE model, when selecting service option for equipment repair and maintenance.

There is no “one way” to go about reducing costs. According to Tudor, et al (1994), the combination of technical expertise, responsiveness, motivated employees, preventive maintenance programs, risk protection, and documentation can make it possible for a healthcare organization to achieve significant cost savings in the area of biomedical equipment maintenance and repair.

Despite the benefits of the ratio analysis technique, care must be exercised when interpreting and utilizing these ratios for decision making. These performance ratios represent average conditions that existed in the past. The peculiarities of the past may not necessarily present themselves in the future.

It should also be stated that consideration was not given to the costs of purchased medical equipment maintenance service contracts because of inadequate data. These costs may provide further insight into why one medical center is more efficient than another one. Furthermore, an investigation of how many equipment items are being maintained and productively used by health care providers as opposed to the number of equipment items requiring periodic preventive maintenance but receiving little or no clinical use would be very useful. Continuing preventive maintenance on excess equipment can lead to

unnecessary costs of operation.

This is the first study that applied a three-prong approach to cost-control in equipment management. The implication of this study is that cost-effective equipment management techniques can be employed to increase efficiency and thereby reduce overhead costs. Moreover, the statistically significant variables identified should be taken into consideration by equipment managers when making service contract decisions. Finally, as supported by the discussion above, the answer to the question posed by this study as to whether there is a potential cost savings opportunity in medical equipment maintenance programs, is a resounding yes.

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Appendix A

Attributes of a Maintenance Service Option

1. Cost: This is the cost associated with the service option. This is usually a contract cost for a period of one year. However, option year costs can also be negotiated in advance.
2. Service Personnel: This relates to the perceived effectiveness of the individuals within the facilities or those from outside contractors who are charged with the responsibility of performing preventive maintenance or repair on medical equipment.
3. Location: This has to do with the proximity of the service provider to the health care facility.
4. Backup Location: This is important especially when the primary location, for whatever reason, is not in the position to provide required service at a particular time.
5. Number of Staff: This is the combined number of staff maintained by the service provider in the primary and backup locations.
6. Qualifications: This relates to the qualifications of the service personnel. How well do their qualifications meet required maintenance needs in terms of the sophistication of the equipment in the facility’s inventory?

Appendix A (cont'd)

7. Service Hours: Is the service provider available 24 hours? Does it cost extra for services provided after normal working hours?

8. Response Time: How soon can/does the service provider respond to service calls?
9. Parts Availability: This relates to the availability of replacement parts. This factor is especially crucial with third-party service providers and in-house maintenance. Delay in obtaining parts from manufacturers may significantly hinder the facility's ability to provide prompt and quality health care.
10. Service Manual: This relates to the service manual availability. This is crucial if maintenance is to be done in-house.
11. Training: In addition to basic training received from biomedical repair school, it is important to determine if manufacturer or third party training is available to biomedical repair staff. This is of primary concern when maintenance is done in-house.
12. Loaner Equipment: This relates to loaner equipment availability. Medical equipment is very crucial to the operations of a health care facility. Therefore, during long period of downtime due to repair and maintenance, the provision of loaner equipment by the service contractor is very essential to the continuity of care.

Appendix A (cont'd)

13. Service Hotline: Sometimes equipment critical to the provision of health care fails without warning. In such emergency situations, the availability of a service hotline is crucial. When service hotlines are available, the facility can promptly report a breakdown and request service without any unnecessary delays.
14. Organization Stability: This has to do with continuity. Is the organization a viable going concern, or does there exist a potential for business dissolution? Organizations, such as the local Chamber of Commerce can usually provide information that might be useful in making this determination.
15. Penalty: Are there penalties for using a third-party provider?
16. Insurance: Does the service provider carry general liability and workers' compensation insurance which cover damages, claims and suits arising from the negligence or non-performance of contractual agreement?
17. Manufacturer Support: This addresses the issue of what type and amount of support can be expected from the manufacturer even when equipment maintenance and repairs are being done in-house or by a third-party service provider.

Appendix A (cont’d)

18. Quality of Service: Overall, how does the service provider fare in terms of the quality of service provided. Based on experience and references, what is the downtime rate of the equipment serviced by the service provider?

Appendix B

Operational Variables

Variable	Operational Definition
Dependent Variable Maintenance costs	 Equipment maintenance costs
Independent Variables Service Option	 Categorical variable set representing service options (2 categories, binary-coded 1,0, to reflect in-house maintenance and annual service contract)
Equipment Age	Categorical variable set (3 categories, binary-coded 1,0, to reflect new, fairly new, and used equipment)
Acquisition Cost	Categorical variable set (3 Categories, binary-coded 1,0, to reflect high, medium and low acquisition cost)
Equipment Type	Categorical variable representing equipment type (2 categories, binary-coded 1,0, to reflect laboratory and radiology equipment)
Usage Rate	Categorical variable set (3 categories, binary-coded 1,0, to reflect high, medium, and low rate of usage)

Appendix C

The JUDGE Model: Assessment of Six Maintenance Service Options

			(Vj)	(1wj)	(2wj)	(3wj)	(4wj)	(5wj)	(6wj)							
	9-point	Coded	Rescaled	Alt	Alt	Alt	Alt	Alt	Alt	Weighted Composite						
Attributes	Rating	Rating	Rating	A	B	C	D	E	F	Alt. A	Alt. B	Alt. C	Alt. D	Alt. E	Alt. F	
Cost	9	4	14.29	0.20	0.10	0.15	0.13	0.17	0.25	2.86	1.43	2.14	1.86	2.43	3.57	
Service Personnel	8	3	10.71	0.13	0.20	0.20	0.16	0.16	0.15	1.39	2.14	2.14	1.71	1.71	1.61	
Location	7	2	7.14	0.25	0.15	0.15	0.15	0.15	0.15	1.79	1.07	1.07	1.07	1.07	1.07	
Backup Location	7	2	7.14	0.25	0.18	0.18	0.13	0.13	0.13	1.79	1.29	1.29	0.93	0.93	0.93	
No. Of Staff	6	1	3.57	0.15	0.20	0.20	0.15	0.15	0.15	0.54	0.71	0.71	0.54	0.54	0.54	
Qualifications	8	3	10.71	0.12	0.20	0.20	0.16	0.16	0.16	1.29	2.14	2.14	1.71	1.71	1.71	
Service Hours	7	2	7.14	0.20	0.16	0.16	0.16	0.16	0.16	1.43	1.14	1.14	1.14	1.14	1.14	
Response Time	8	3	10.71	0.20	0.16	0.16	0.16	0.16	0.16	2.14	1.71	1.71	1.71	1.71	1.71	
Parts Availability	6	1	3.57	0.13	0.22	0.22	0.17	0.12	0.14	0.46	0.79	0.79	0.61	0.43	0.50	
Service Manual	6	1	3.57	0.13	0.22	0.22	0.17	0.12	0.14	0.46	0.79	0.79	0.61	0.43	0.50	
Training	6	1	3.57	0.13	0.22	0.22	0.17	0.12	0.14	0.46	0.79	0.79	0.61	0.43	0.50	
Loaner Equipment	6	1	3.57	0	0.25	0.25	0.16	0.16	0.18	0	0.89	0.89	0.57	0.57	0.64	
Service Hotline	6	1	3.57	0.13	0.22	0.22	0.17	0.12	0.14	0.46	0.79	0.79	0.61	0.43	0.50	
Org. Stability	6	1	3.57	0.17	0.22	0.22	0.13	0.12	0.14	0.61	0.79	0.79	0.46	0.43	0.50	
Penalty	1	-4	-14.29	0	0.25	0.25	0.18	0.18	0.14	0	-3.57	-3.57	-2.57	-2.57	-2.00	
Insurance	6	1	3.57	0.12	0.20	0.20	0.16	0.16	0.16	0.43	0.71	0.71	0.57	0.57	0.57	
Manufac. Support	6	1	3.57	0.13	0.25	0.25	0.12	0.12	0.13	0.46	0.89	0.89	0.43	0.43	0.46	
Quality	9	4	14.29	0.13	0.22	0.22	0.17	0.12	0.14	1.86	3.14	3.14	2.43	1.71	2.00	
		28														
Scaling Factor		3.57														
Totals			100							18.43	17.64	18.36	15.00	14.11	16.46	100

Note. See the next page for "Key".

Appendix C (cont'd)

<u>Key.</u>

Column A = Attribute names

Column B = 9-point rating of each attribute

Column C = Coded rating by subtracting 5 from each 9 point-rating

Column D = Each attribute is rescaled by multiplying the scaling factor by the coded rating

Column E = Weighted utility of each attribute for Alternative A (In-house Service)

Column F = Weighted utility of each attribute for Alternative B (Manufacturer Contract)

Column G = Weighted utility of each attribute for Alternative C (Manufacturer Demand)

Column H = Weighted utility of each attribute for Alternative D (Third-party Contract)

Column I = Weighted utility of each attribute for Alternative E (Third-party Demand)

Column J = Weighted utility of each attribute for Alternative F (Maintenance Insurance)

Column K = Weighted utility of each attribute for Alternative A multiplied by the rescaled rating

Column L = Weighted utility of each attribute for Alternative B multiplied by the rescaled rating

Column M = Weighted utility of each attribute for Alternative C multiplied by the rescaled rating

Column N = Weighted utility of each attribute for Alternative D multiplied by the rescaled rating

Column O = Weighted utility of each attribute for Alternative E multiplied by the rescaled rating

Column P = Weighted utility of each attribute for Alternative F multiplied by the rescaled rating

Appendix D

Biomedical Repair Expenses Data

Table 1

BAMC's Total Obligations and Biomedical Repair Expenses

Description	1996 ('000)	1997 ('000)	1998 ('000)
Facility's Direct Obligations	$257,942	$247,585	$250,569
Total Biomedical Repair Expenses	$3,977	3,761	5,407
Direct Expenses	$3,480	3,348	4,806
Personnel Expenses	1,472	1,367	1,144
Repair Hours	34	31	22

Table 2

Madigan's Total Obligations and Biomedical Repair Expenses

Description	1996 ('000)	1997 ('000)	1998 ('000)
Facility's Direct Obligations	$229,998	$225,176	$236,911
Total Biomedical Repair Expenses	$3,692	4,859	2,727
Direct Expenses	$3,373	4,463	2,404
Personnel Expenses	1,246	1,391	1,340
Repair Hours	16	20	22

Table 3

Tripler's Total Obligations and Biomedical Repair Expenses

Description	1996 ('000)	1997 ('000)	1998 ('000)
Facility's Direct Obligations	$240,497	$230,264	$289,870
Total Biomedical Repair Expenses	$4,006	3,912	4,215
Direct Expenses	$3,529	3,482	3,804
Personnel Expenses	1,324	1,290	1,242
Repair Hours	33	32	23

Appendix E

Biomedical Repair
Hours of Service Provided to Production Centers

PRODUCTION CENTER	BAMC		MADIGAN		TRIPLER	
	Hours	%	Hours	%	Hours	%
1996						
Inpatient Services	4773	48	1913	29	4771	39
Outpatient Services	3581	36	3582	55	5675	46
Dental Services	1663	16	1066	16	1851	15
Totals	10017	100	6561	100	12297	100
1997						
Inpatient Services	3264	40	2437	28	3802	35
Outpatient Services	3732	46	4739	54	5394	49
Dental Services	1078	14	1680	18	1793	16
Totals	8074	100	8856	100	10989	100
1998						
Inpatient Services	1661	27	2653	28	2727	33
Outpatient Services	3764	61	5086	53	4202	51
Dental Services	756	12	1820	19	1286	16
Totals	6181	100	9559	100	8215	100

Appendix F

Definitions

1. New equipment: Equipment still under warranty and/or less than 10% of its useful life.
2. Fairly New: Equipment not under warranty and between 10% and 30% its useful life.
3. Used Equipment: Equipment not under warranty, and over 30% of its useful life.
4. High Acquisition Cost: Equipment costing over $100,000.
5. Medium Acquisition Cost: Equipment costing between $10,000 and $100,000.
6. Low Acquisition Cost: Equipment costing less than $10,000
7. High Usage Rate: Equipment used over 70% of capacity.
8. Medium Usage Rate: Equipment used between 40% and 70% of capacity.
9. Low Usage Rate: Equipment used less than 40% of capacity.
10. Biomedical repair expense to total facility's obligation: This represents the percentage of the total direct obligations by the medical treatment facility that is consumed by Biomedical department in a particular year. An excessively high ratio might indicate inefficiencies in the Biomedical repair department.
11. Biomedical personnel cost to total Biomedical expense: This is a generalized expression of the relationship between the amount expended on personnel salaries and the overall expenses incurred in the Biomedical department. It is a measure of how much of one of the inputs (personnel) is used by the department.

Appendix F (cont'd)

12. Biomedical expense per repair hour: This measure is derived by dividing the total biomedical department expenses by the total hours of services provided in a given year. The resulting dollar amount when compared over a period of time can signal favorable or unfavorable turns.

13. Biomedical expense per case-mix adjusted disposition: This ratio is computed by dividing the total Biomedical expenses by case-mix adjusted dispositions. Dispositions were adjusted for acuity in order to make for better comparability to the other medical centers.

14. Biomedical expense per outpatient visit: This ratio describes how much biomedical repair costs are incurred for each outpatient visit. Dividing total biomedical repair expenses by total outpatient visits derives this performance ratio.

Appendix G

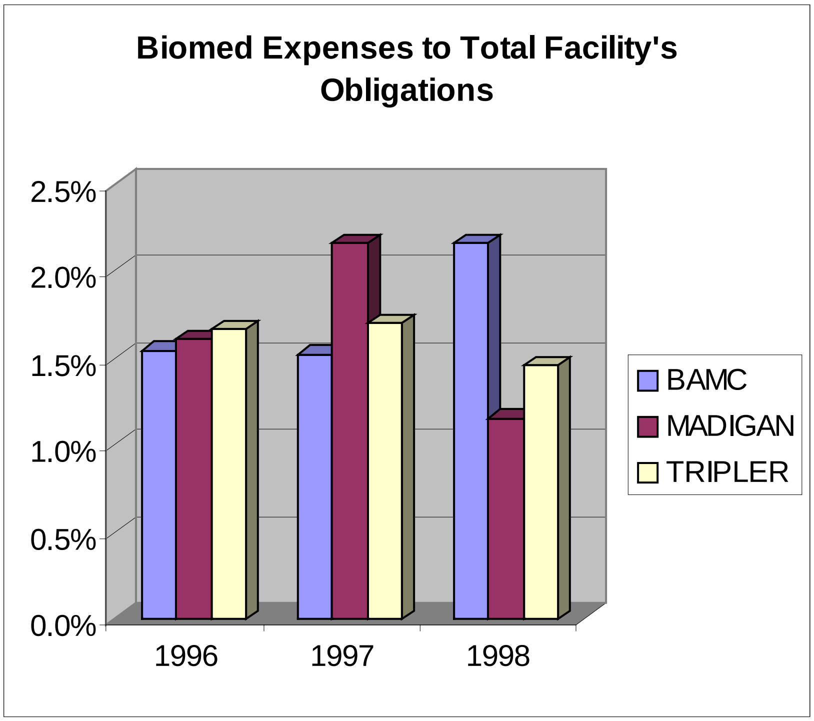
Direct Care Workload

Description	Volume BAMC	MADIGAN	TRIPLER
1996			
Inpatient Dispositions	17,287	19,530	19,587
Outpatient Visits	593,712	989,822	843,624
Case Mix Index	1.473	1.063	1.0153
1997			
Inpatient Dispositions	10,410	14,750	15,357
Outpatient Visits	638,587	944,338	782,570
Case Mix Index	1.6093	1.0144	.9355
1998			
Inpatient Dispositions	9,385	10,675	14,342
Outpatient Visits	634,004	913,605	756,023
Case Mix Index	1.607	1.0709	.8896

Appendix H

Performance Indicators

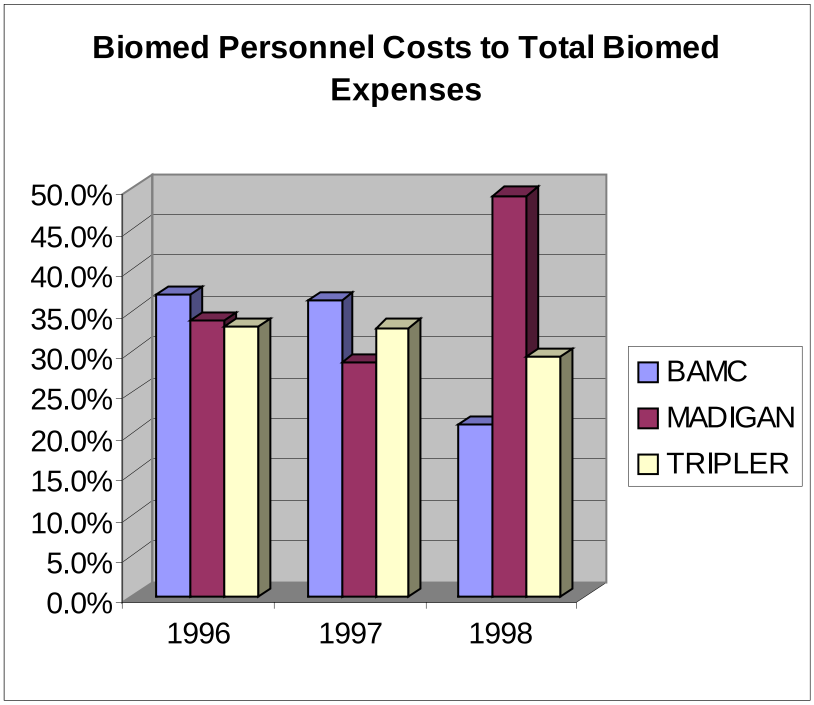
Figure 1



Appendix H (cont'd)

Performance Indicators

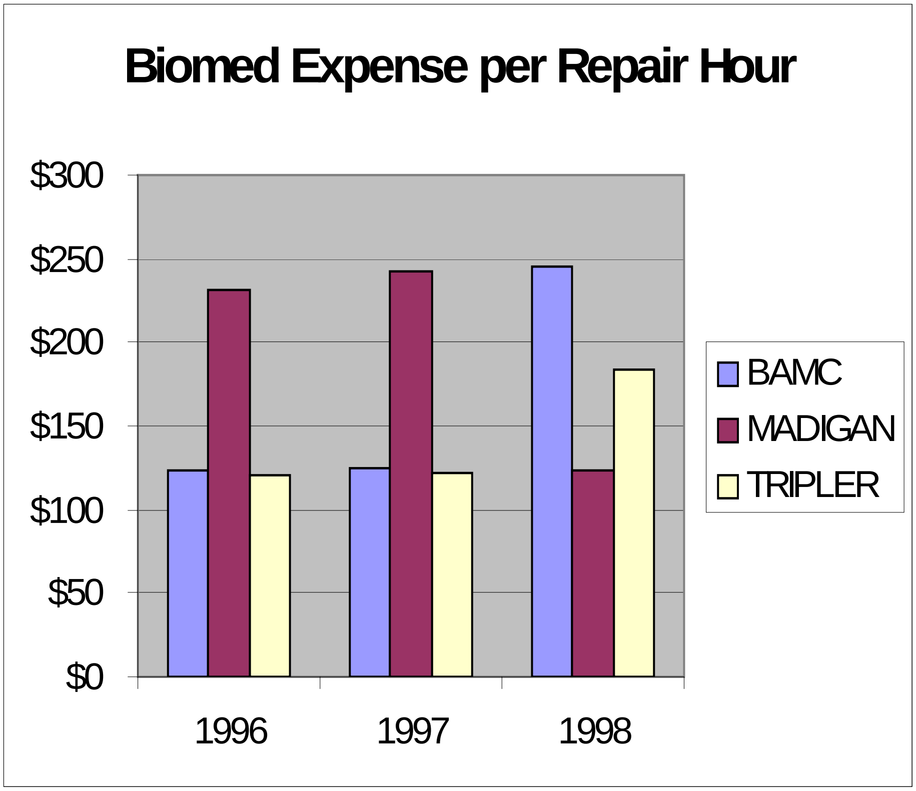
Figure 2



Appendix H (cont'd)

Performance Indicators

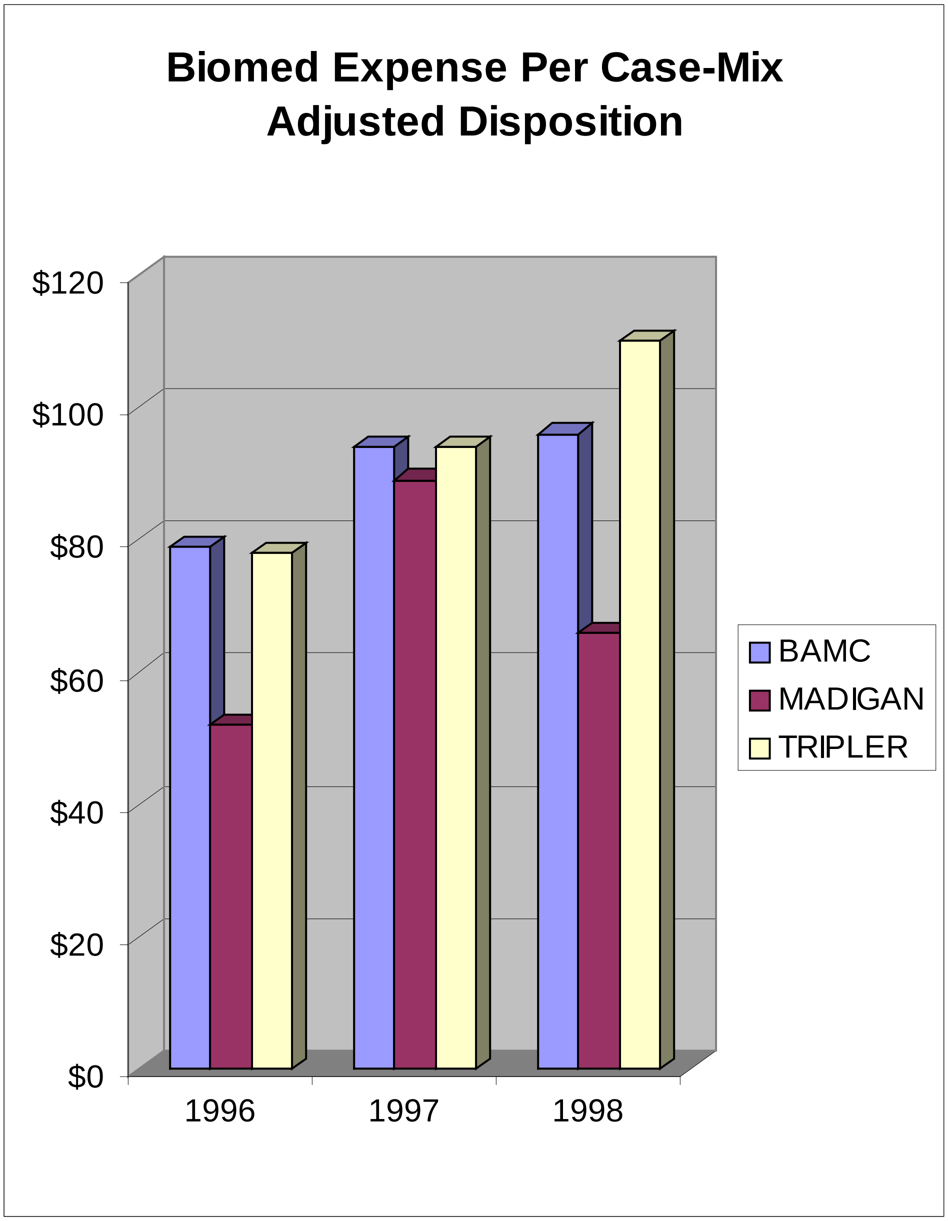
Figure 3



Appendix H (cont'd)

Performance Indicators

Figure 4



Appendix H (cont'd)

Performance Indicators

Figure 5